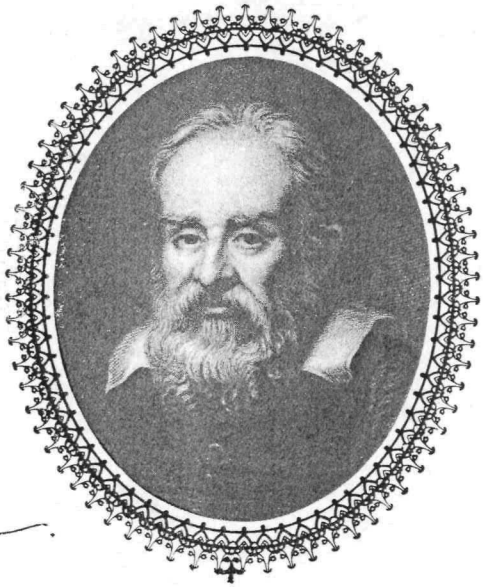

ATOMIC PIONEERS

Book 1

From Ancient Greece to the 19th Century

by Ray, and Roselyn Hiebert

A WORLD OF THE ATOM SERIES BOOKLET

The Authors

Mrs. Roselyn Hiebert received her B.A. degree from the University of California. She and her husband, Dr. Ray Hiebert, have written the following books for children: *Franklin Delano Roosevelt: President for the People,* 1968; *Thomas Edison: American Inventor,* 1969; and *The Stock Market Crash of 1929,* 1970, Franklin Watts, Inc.

Dr. Ray Hiebert received his B.A. degree from Stanford University, his M.S. degree from Columbia University, and his M.A. and Ph.D. degrees from the University of Maryland. He is Professor and Head of the Journalism Department at the University of Maryland. Dr. Hiebert is editor of *Books in Human Development,* Agency for International Development, 1965, *The Press in Washington,* Dodd, Mead and Company, 1966, and a series of textbooks on government and communications for John Wiley and Sons, Inc. He is the author of a biography, *Courtier to the Crowd,* Iowa State University Press, 1966.

The Cover

Left to right, top row, Michael Faraday, Joseph Henry, and Dmitri Mendeléev; middle row, Stanislao Cannizzaro, Max Planck, and Lord Rayleigh; bottom row, Marie Curie, Pieter Zeeman, and Frederick Soddy.

THE WORLD OF THE ATOM SERIES

Foreword

This booklet is one in a series for junior high school science students and their teachers It is the first of a group of four biographical booklets which will describe the contributions to atomic science made by 100 individuals over a 2550 year time span This volume covers the period from the 5th century B C to the middle of the 19th century

I hope you enjoy reading about the lives of these important men

Edward J. Brunenkant

Edward J Brunenkant, Director
Division of Technical Information

Preface

The idea that matter is made up of atoms goes back almost 2500 years—500 years before the birth of Christ. In ancient Greece, philosophers, who were concerned with the nature of the world, first developed the idea that matter was composed of atoms.

The ancient Greeks were not scientists in the modern sense of the word. They rarely experimented. They reached their conclusions primarily through deductive reasoning, logic, and mathematics.

Their reasoning was ignored for many centuries, however, largely because religious thinkers considered the atomic theory to be a materialistic view of the world that denied the existence of spiritual forces.

It was not until the scientific revolution starting in the 16th and 17th centuries that men began to examine the world experimentally. The 18th century was a period of swift gain in scientific knowledge. And by the beginning of the 19th century, scientists, such as John Dalton and Jöns Jakob Berzelius, revived the atomic idea by using quantitative, experimental data.

Perhaps one way to understand anything complex is to examine its historical development. And one way to look at history is through the lives of the men who made it. Thus this brief booklet is intended to give a snapshot view of 25 men, each of whom contributed an important building block to the foundations of atomic science.

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Division of Technical Information

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PYTHAGORAS

Pythagoras (pith-ag-o-rus) was one of the first great mathematicians and scientists in man's recorded history. He was born about 582 B.C. on Samos, an Aegean island. He died about 497 B.C. in Metapontum in southern Italy.

Biographical Details

While still a young man, Pythagoras left his native Greek island for Egypt, where he spent 22 years studying arithmetic and geometry. He then traveled to Babylon to spend 12 years studying arithmetic, music, and various other subjects.

When he was 56 years old, he returned to Greece. There, at Croton, he established a school that soon became famous. His students were ardent disciples and took the name Pythagoreans.

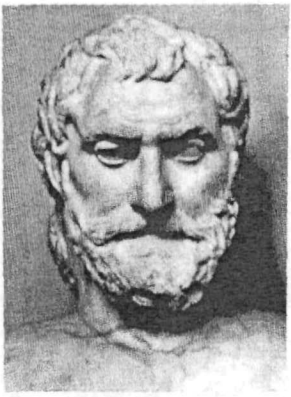
He was forced to leave Greece because, according to some sources, men were jealous of his popularity. He spent his last years in southern Italy.

Scientific Achievements

Pythagoras contributed much to the developing sciences of geometry, astronomy, and even the science of sound and music. He is most famous for his Pythagorean theorem, which is well known to all geometry students. (The square of the length of the hypotenuse of a right triangle is equal to the sum of the squares of the lengths of its sides.)

Some earlier Greek philosophers believed that matter was composed of one element. Thales (thay-leez) thought everything was water, Anaximenes (an'ak-sim'ih-neez) thought all matter was really air, and Heraclitus (her-uh-kly'tus) thought fire was the primary element.

Pythagoras rejected the idea of one element and held that matter was composed of four parts: earth, water, air, and fire. He felt that these four elements existed in various combinations with four qualities: hot and cold, wet and dry.



Thales

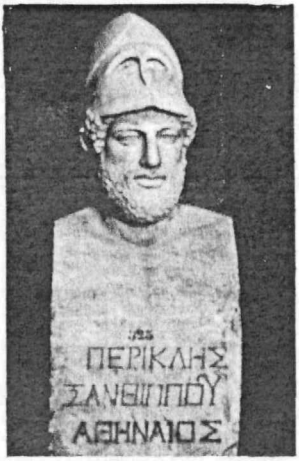
Contribution to Atomic Science

Pythagoras opposed the idea of atomicity, but he stimulated Greek philosophers to give serious consideration to the nature of matter. Some later returned to the idea of one substance, the atom. They were called atomists.

ANAXAGORAS

Anaxagoras (an-ak-zag'oh-rus), the first teacher of science in Athens, could be called the world's first theoretical physicist. He was born about 500 B.C. at Clazomanae, an Ionian city in Asia Minor. He died in 428 B.C. in Lampsacus (now Lâpseki, Turkey).

Biographical Details



Pericles

As a young man, Anaxagoras probably moved to a nearby city, Ephesus, then a great center of learning. There he no doubt came under the influence of Heraclitus, the philosopher who thought all matter was fire.

Soon after the Persian wars, he moved to Athens. He became a close friend and advisor to Pericles (pear-i-cleez), the most powerful man in Athens. For awhile, he was a man of wide influence.

But he was a philosopher and could not understand much of the Athenians' religious superstition. Because he questioned these superstitions, he was banished from Athens and spent the rest of his life in exile.

Historians call him the first man in recorded history who was punished for following his reason and scientific thought.

Scientific Achievements

Anaxagoras reasoned that the universe was composed of an infinite variety of seeds. These seeds were set into motion and order by the mind, which was a subtle fluid that transformed the chaos of the world into intelligible matter. The composition of these seeds was the same. They were different only in size.

Through his reasoning alone, Anaxagoras came close to some aspects of modern atomic theories.

Contribution to Atomic Science

Anaxagoras' theories were a compromise between the "single substance" ideas of the universe of the mystic philosophers of his native Ionia and the "multiple substance" suggestions of the Pythagoreans.

EMPEDOCLES

Empedocles (im-ped-oh-kleez) is known not only as a philosopher, but also as a poet, physicist, social reformer, mystic, and physician. He was born about 490 B.C. at Agrigentum, Sicily. He died about 430 B.C., possibly at Mount Etna.

Biographical Details

Empedocles' birthplace was one of the most beautiful cities of the ancient world. When the Pythagoreans were driven out of Croton, they found refuge in Agrigentum. Empedocles was certainly inspired by the ferment of ideas and Greek culture in his hometown.

As a physician, Empedocles made many medical discoveries. He found that the marshy lands around his native city were unhealthy, and he sought to drain them, sometimes using his own funds to do so.

He spent his life traveling from town to town, singing his poetry, "purifying" the souls of men, and healing their bodies.

It is said that he died by jumping into the volcanic crater of Mount Etna, thinking that he would be taken up to heaven and made into a god.

Scientific Achievements

Like Pythagoras, Empedocles felt that matter was composed of four elements: fire, air, water, and earth.

But he suggested that there were two moving forces that made elements combine or separate into different substances. The combining force was love. The separating force was hate. These two forces, operating on the

four elements made possible all the combinations of matter.

Contribution to Atomic Science

Empedocles provided one further step toward an atomic theory. Aristotle (air-ris-ta-tell) improved his idea of four elements uniting in different proportions to explain all substances known to man, and it remained essentially the basis of chemical theory for over 2000 years.

Coin of Selinus honoring Empedocles' work in containing an epidemic.

LEUCIPPUS

Leucippus (loo-sip'us) was the world's first actual atomist. The dates and places of his birth and death are unknown, but he flourished in Miletus and Abdera, Thrace, around 450 B.C.

Zeno

Biographical Details

Little is known of Leucippus. He probably studied under Zeno in Elea. Zeno presented Greek thinkers with paradoxes caused by the assumption that time and space were infinitely divisible.

In trying to avoid these paradoxes, Leucippus and his pupils searched for the indivisibility of matter. They believed they found it in the idea of atoms, out of which all matter was composed.

Leucippus founded his own school in Abdera.

Scientific Achievements

Called the inventor of atomism, Leucippus was the first to state the rule of causality: "Nothing happens without reason; everything has a cause and is the result of a necessity."

This principle of causation, a basic idea of physics, made possible the idea of a mechanistic world, where matter could be conceived in terms of simpler elements composed of atoms.

Contribution to Atomic Science

Leucippus' work was overshadowed by his student. It was Democritus who took these basic ideas and developed them into a consistent explanation of the physical world.

DEMOCRITUS

Democritus (de-mock-rye-tus) was the world's first great atomic philosopher. He was born in Abdera, Thrace, around 460 B.C., and died, place unknown, about 380 B.C.

Biographical Details

After studying under Leucippus in Abdera, Democritus resolved to spend his inheritance in research abroad. He traveled widely, studying in Egypt for 5 years and then journeying to Chaldea, Babylon, Persia, and possibly India.

He was interested in all branches of philosophy and gained wide knowledge of mathematics, astronomy, and medicine. But during his lifetime he himself lived in the shadow of another Greek philosopher, Socrates (sock-ray-tees). Democritus once went to Athens and saw Socrates but was too shy to introduce himself.

He wrote many books, but they are not known to us. His interest in ethics led him to write many proverbs, which were the accumulated wisdom of his people. He was a cheerful philosopher and lived to the age of 80.

Socrates

Scientific Achievements

For Democritus, the world was made of only two things: The vacuum of empty space, and the fullness of matter. All matter consisted of particles, so small that nothing smaller could be imagined.

These particles were indivisible. The word atom itself means "that which cannot be cut". These atoms were eternal, unchangeable, and indestructible. They differed from

each other only in physical shape, and this allowed them to form different substances.

Democritus' theory of atoms led him to expound an explanation of the world that was completely mechanical. He reasoned there was no such thing as spirit apart from matter. He postulated special "soul" atoms. The universe was the blind result of swirling atoms. These atoms, through their motions, clumped together forming worlds.

Contribution to Atomic Science

Although long overshadowed by his contemporary, Socrates, Democritus nevertheless was the most successful of the Greek philosopher–scientists in the correctness of his theories.

Of course, his ideas were based strictly on deductive reasoning, not on experimenting and testing. Yet his view of the world was much closer to our 20th century concepts than that of most other Greek philosophers.

EPICURUS

Epicurus (ep-i-ku-rus) developed a consistent ethical system based on atomism. He was born at Samos in 342 B.C. and died in Athens in 270 B.C.

Biographical Details

Epicurus was the son of a noble Athenian family, but his parents had moved to the island of Samos, where he was born. After a precocious childhood, he went to Athens to study at the age of 14.

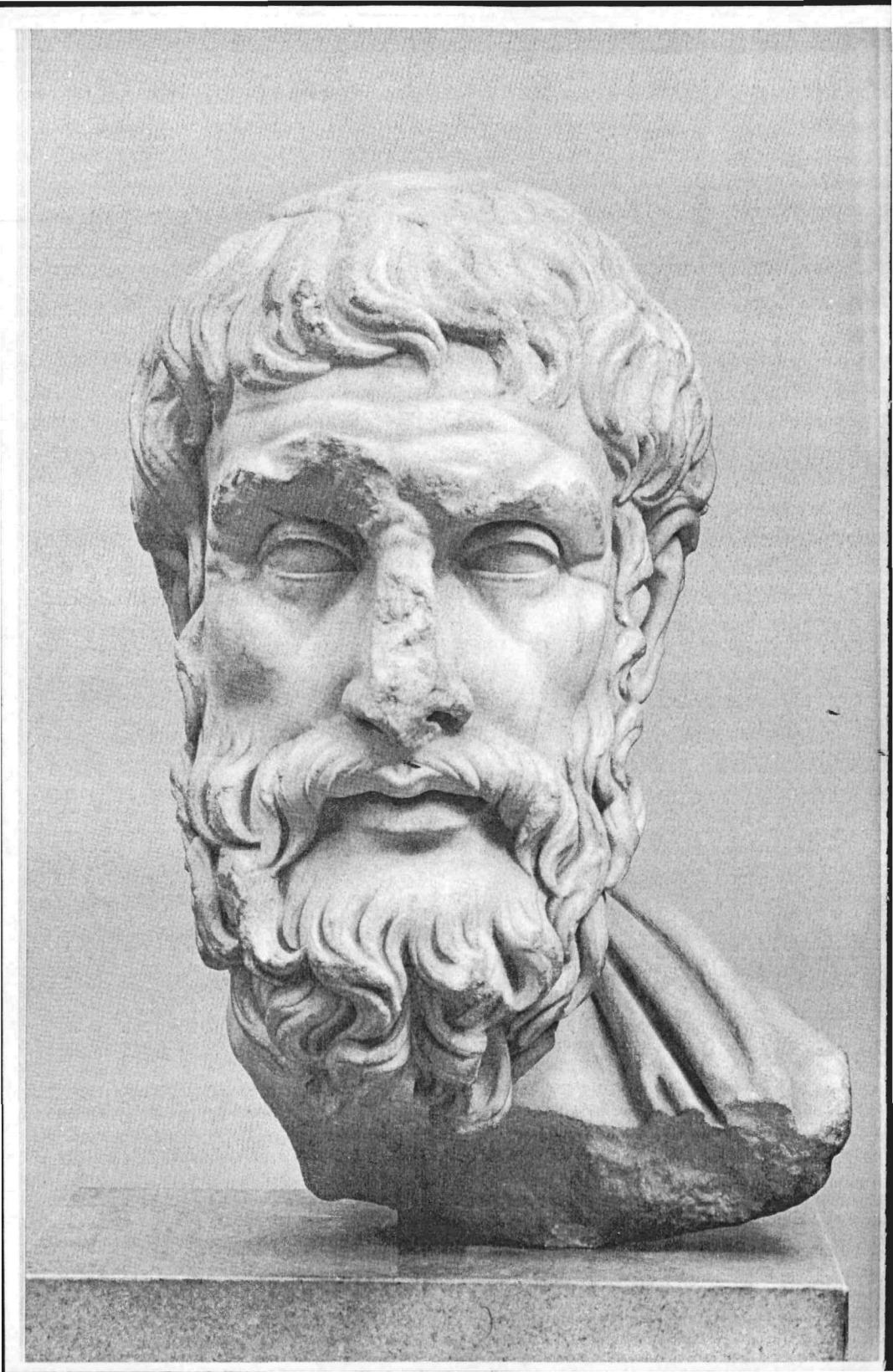
In his early manhood he roamed the Asiatic coast, and at 30 became an independent philosopher. He established his own school and ultimately returned to Athens with a popular following. His disciples called themselves Epicureans.

Epicurus was the first philosopher to allow women to study in his school. His popularity and success caused much jealousy and many attacks, but these only strengthened the devotion of his followers.

Scientific Achievements

Epicurus led a reaction against the idealist philosophy of Plato and Aristotle. He returned to the materialistic ideas of the atomists. He taught the theory of atoms as part of a complete philosophy of ethics, psychology, and physics.

The main physical theory of Epicurus was the atomic theory. Everything, whether material or spiritual, is made of atoms. Since the physical world was the real world, Epicurus felt that physical pleasure was the best goal, and that all knowledge was derived only from the physical senses.



He felt that the greatest pleasure was that which came from the exercise of virtue, that pleasure came from moderation, from having "nothing too much", and from avoiding pain and trouble.

Contribution to Atomic Science

The atomism of Democritus represented an achievement in Greek philosophy. However, it was too materialistic for mystics and some philosophers, and it never had the influence of the idealism* of Plato and Socrates.

Epicurus revived interest in the atomic explanation of the world. But his philosophy, too, was misunderstood and attacked for being irreligious, and the word Epicureanism has come to mean being fond of luxury and sensuous pleasure.

*Plato's idealistic philosophy stated that man must go beyond the material world of his senses to discover the intellectual world of ideas and forms that could be grasped by the mind alone. He knew that the ideal state which he envisioned, where man possessed the virtues of temperance, wisdom, and courage, could not be perfectly attained in this world, but he thought it was a worthy goal toward which man could strive.

ARCHIMEDES

Archimedes (are-ki-mee-deez) was perhaps the greatest scientist and mathematician of ancient times. He was born in Syracuse, Sicily, about 287 B.C. and died there about 212 B.C.

Biographical Details

Archimedes was the son of the astronomer Pheidias (fid-dee-us), and a relative and friend of Hieron (high-ron) II, King of Syracuse. He spent some time studying in Egypt, and while in Alexandria he invented the hydraulic screw, which was a device for raising water. It consisted of a screw fitting tightly into a cylindrical case. When the lower end was put into water, the upper end was turned by a handle. Water was raised from one spiral of the screw to the next until it flowed out the top.

He returned to spend most of his life in Syracuse and he died during a Roman siege of that city.

Scientific Achievements

Archimedes' discoveries and inventions would make a long list. He was the first and greatest of ancient physicists who, like their modern counterparts, used their knowledge of science to defend their country against enemy attack. Archimedes is supposed to have constructed large lenses to set an enemy fleet on fire, and mechanical cranes to turn ships upside down.

He worked out the principle of the lever, calculated a value for "pi",* and designed a planetarium among other discoveries.

*Pi is the ratio of a circle's circumference to its diameter.

Most important, he formulated the idea of the relative densities of bodies: An object placed in a liquid seems to lose an amount of weight equal to the weight of the fluid it displaces. From this same idea, he also derived that a floating object displaces an amount of liquid equal to its own weight. He developed the principle one day while sitting in his bathtub. He noticed that when he got into the tub, he displaced an amount of water equal to the volume of his own body.

Contribution to Atomic Science

Archimedes' idea of the relative densities of bodies helped to show that men could analyze the relative weights of substances. This notion was to become important in the establishment of atomic weights.

LUCRETIUS

Lucretius (loo-kree-shus), whose full name was Titus Lucretius Carus, was a Roman poet and philosopher. He was born in Rome about 95 B.C. and died there about 55 B.C.

Biographical Details

Lucretius came from a good Roman family and was well educated. He is known today chiefly for one work, a very long poem called *De Rerum Natura* ("On the Nature of Things").

It is said that he committed suicide when he was 44 years old, but this may have been gossip passed along through the ages by his enemies.

Scientific Achievements

Lucretius was not a scientist or original thinker. Like many great Romans, his greatness was not in having the kind of originality that the Greeks had, but rather in being able to transmit and popularize the originality of the Greeks.

De Rerum Natura was an effective and poetic defense of Epicurean philosophy, particularly of atomism. Lucretius praised Epicurus, and showed that he was well-acquainted with the ideas of Empedocles, Anaxagoras, and the other atomists.

He held that all things were composed of atoms, even immaterial objects, such as mind and soul. He did not deny the existence of God, but even God was made out of atoms. To the very religious, such ideas were impious, and his work was not highly regarded among religious leaders.

Contribution to Atomic Science

Lucretius' poem preserved the ideas of the atomists, but for more than 1000 years, serious study of atoms was driven underground by religious teachers during the middle ages.

COPERNICUS

Copernicus (co-pur-ni-kus), whose real name was Nicolaus Koppernigh, was the first great scientist in the revolution of ideas of the Renaissance* (wren-a-sawn'ce). He was born in Toruń, Poland, February 19, 1473, and died in Frombork, Poland, May 24, 1543.

Biographical Details

Copernicus came from a noble family. His uncle was a prince–bishop who helped him acquire a fine education. As a youth he studied mathematics and painting at Cracow, the intellectual capital of Poland.

In 1496, when Copernicus was 23, he traveled to Italy, where he spent 10 years studying medicine, law, and astronomy.

In Italy he latinized his name and began to work out the details for what we now call the Copernican theory of the universe. He returned to Poland in 1505 and served as canon, physician, and official. He postponed publication of a book explaining his theories until shortly before his death in 1543, perhaps because he feared he would be punished for his heretical views.

Scientific Achievements

Although Copernicus had studied mathematics, he found he could not easily calculate the positions of the planets when he followed the prevailing belief that all heavenly bodies revolved around the earth.

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*Renaissance, which means rebirth, refers to the time between the 14th and 17th centuries in Europe when science, literature, and art blossomed with new ideas and achievements.

He suggested that the earth, instead, revolved around the sun, and he worked out a mathematical system to demonstrate how the positions of planets and stars could be calculated on this basis.

Contribution to Atomic Science

Copernicus helped start the scientific revolution that has continued to the present day. He did this chiefly by turning to mathematics to discover new truths about the universe.

Later atomic scientists showed the importance of mathematics in explaining the world of the atom, similar to the way in which Copernicus used mathematical formulas to explain the solar system. Atomic weights, atomic numbers, the quantum theory, and even Einstein's famous formula, $E = mc^2$, are all mathematical ways of explaining the world.

GIORDANO BRUNO

Giordano Bruno was an Italian philosopher who revived the Greek idea of atoms. He was born in Nola, near Naples, Italy, in January 1548 and died in Rome, February 17, 1600.

Biographical Details

Bruno was a Dominican priest who came under the intellectual influence of the Copernican theories that were spreading in the 16th century. As he studied more about science, he began to express notions that got him into trouble with his religious brethren.

Soon he fled Italy because of his growing doubts about the ideas of the church. He went to Geneva, Switzerland, then to Paris, and in 1582 to Oxford to lecture and study.

In 1592 he returned to Venice, Italy, where he was arrested by the Inquisition* and charged with heresy. His trial lasted 7 years; he was convicted and burned at the stake.

Scientific Achievements

Bruno was not a scientist, but he was an honest seeker who thought out a number of important ideas of modern science. He taught the eternity of the universe. He denied that heavenly bodies contain any matter or element superior to that on earth.

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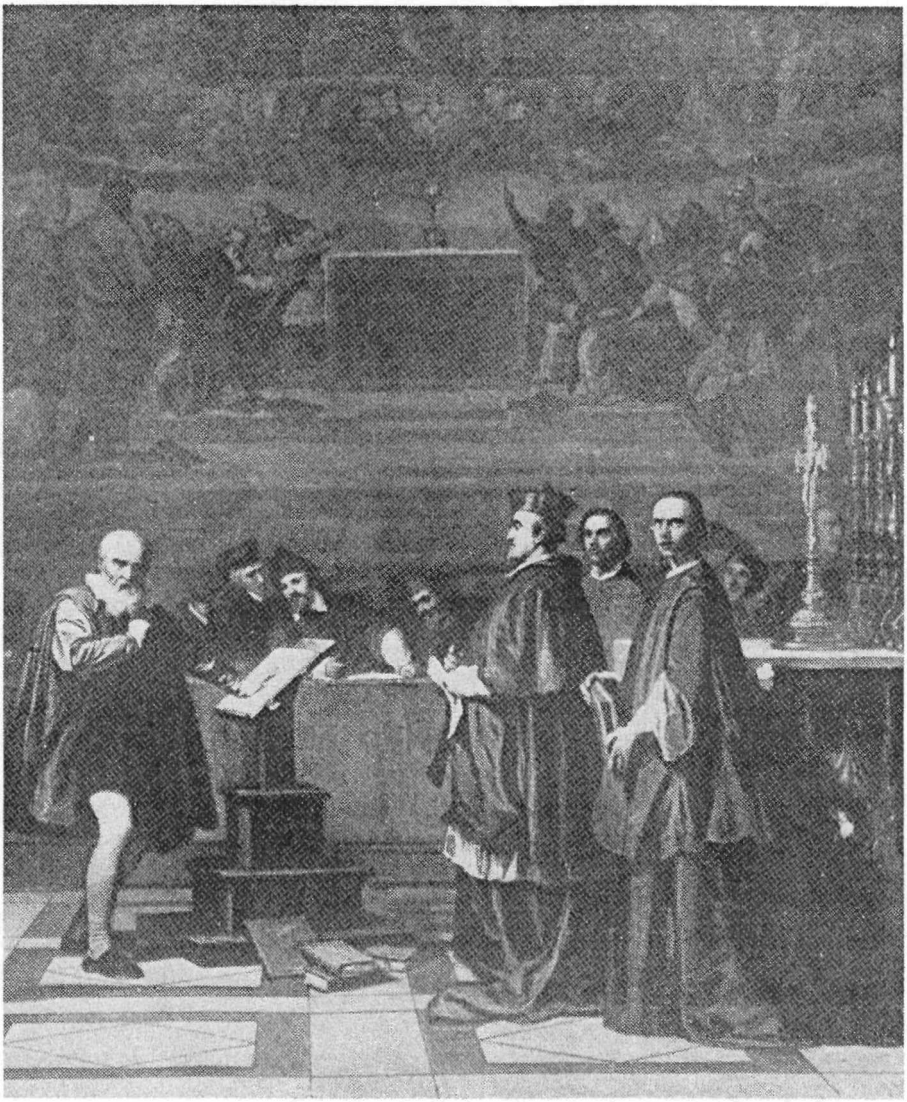
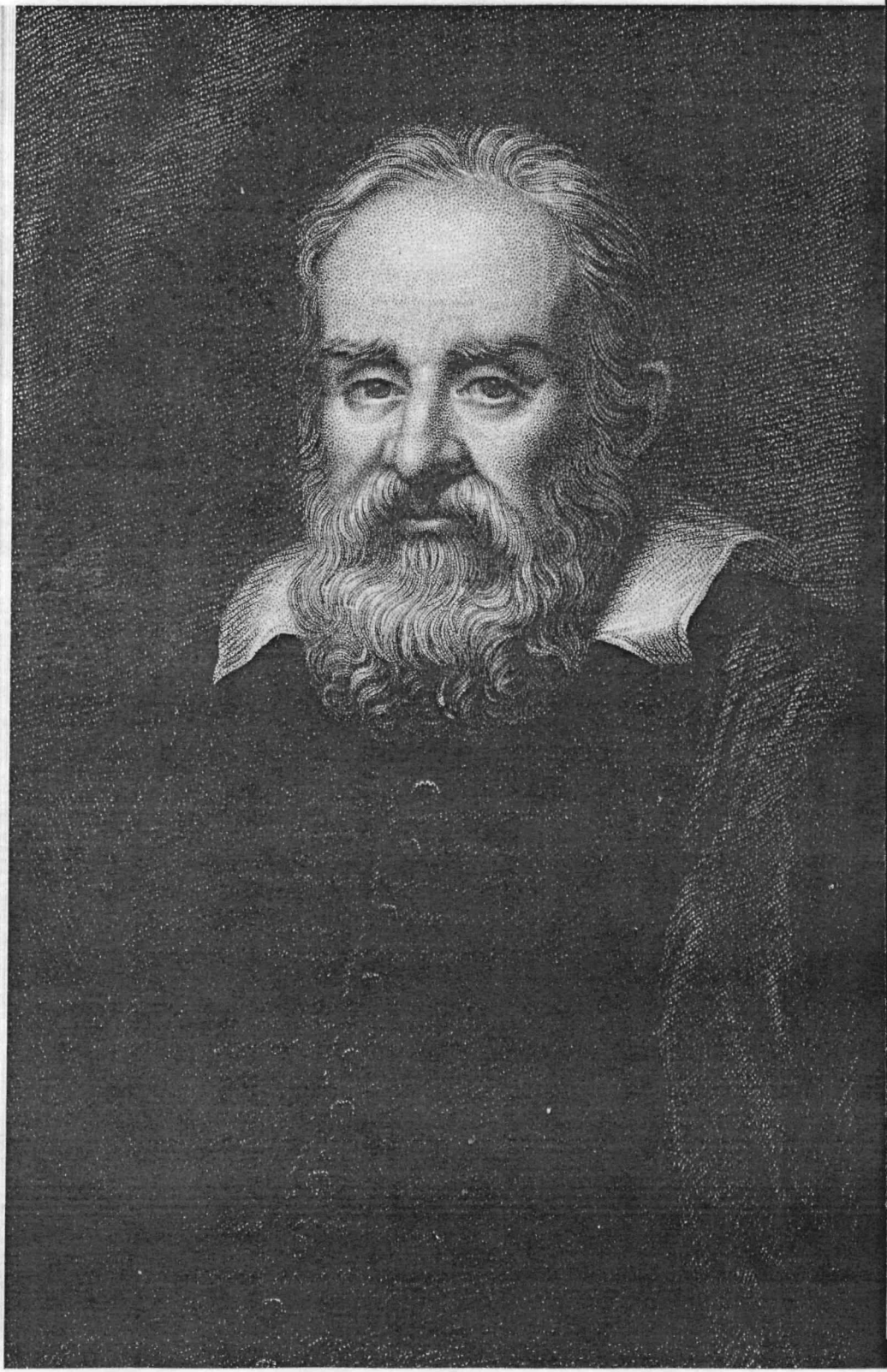
*This was a Roman Catholic group of churchmen set up to uncover, punish, and prevent heresy. Heresy is the belief in ideas that are contrary to those of a particular religion.

Contribution to Atomic Science

Bruno foreshadowed the return to the scientific investigation of matter, which had been interrupted for more than 1000 years.



Inquisition scene.



GALILEO GALILEI

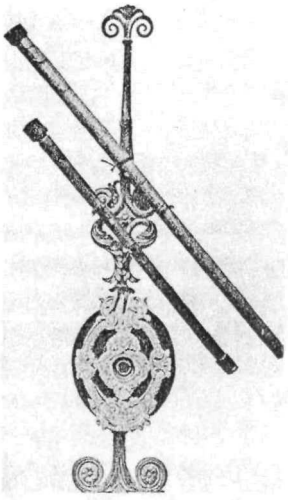
Galileo (gal-i-lay-o) Galilei (gal-i-lay-i), commonly known by his first name only, was the greatest Italian of the scientific revolution.* He was born in Pisa, Italy, February 15, 1564, and died at Arcetri, near Florence, January 8, 1642.

Biographical Details

Galileo's father, a mathematician, wanted his son to study medicine. As a teenager, he was a medical student at the University of Pisa, but he began to make experiments in physics and soon was caught up in mathematics, mechanics, and astronomy.

Throughout his long life, he made experiments that refuted Aristotelian (air-ris-ta-teel-yan) physics and through experiment and empirical observation moved the world of science into the modern era.

Toward the end of his life, he ran into trouble with religious leaders because of his scientific views. He renounced these views in order to save his life, but he continued to make scientific experiments until his death.



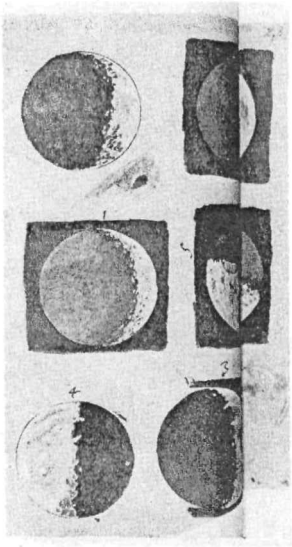
Galileo's telescope.

Scientific Achievements

Galileo made many discoveries in mechanics, physics, and especially astronomy.

He constructed the first workable telescope and was the first man to observe the magnified surface of the moon. He discovered the satellites of Jupiter, the rings of Saturn, and spots on the sun. With his telescope he

*The scientific revolution was a renewed interest in scientific research that began in Europe in the 17th century.



Galileo's drawings of the mountains on the moon.

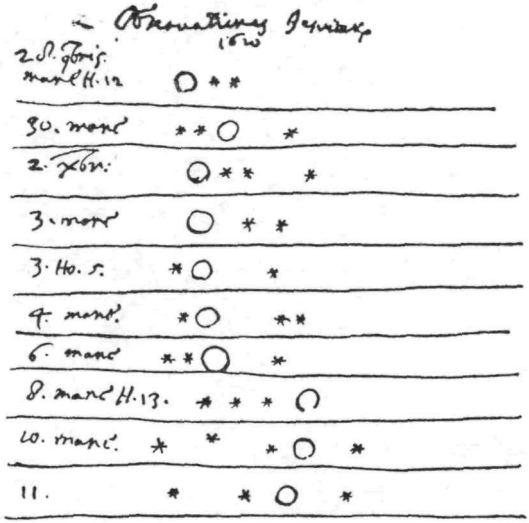
helped to establish the correctness of the Copernican theories that the earth was not the center of the universe, but rather a planet hurtling rapidly through space moving around the sun.

His most original work was the foundation of the science of dynamics. He was concerned with the mathematics and measurement of motion, and is especially noted for his law of falling bodies.

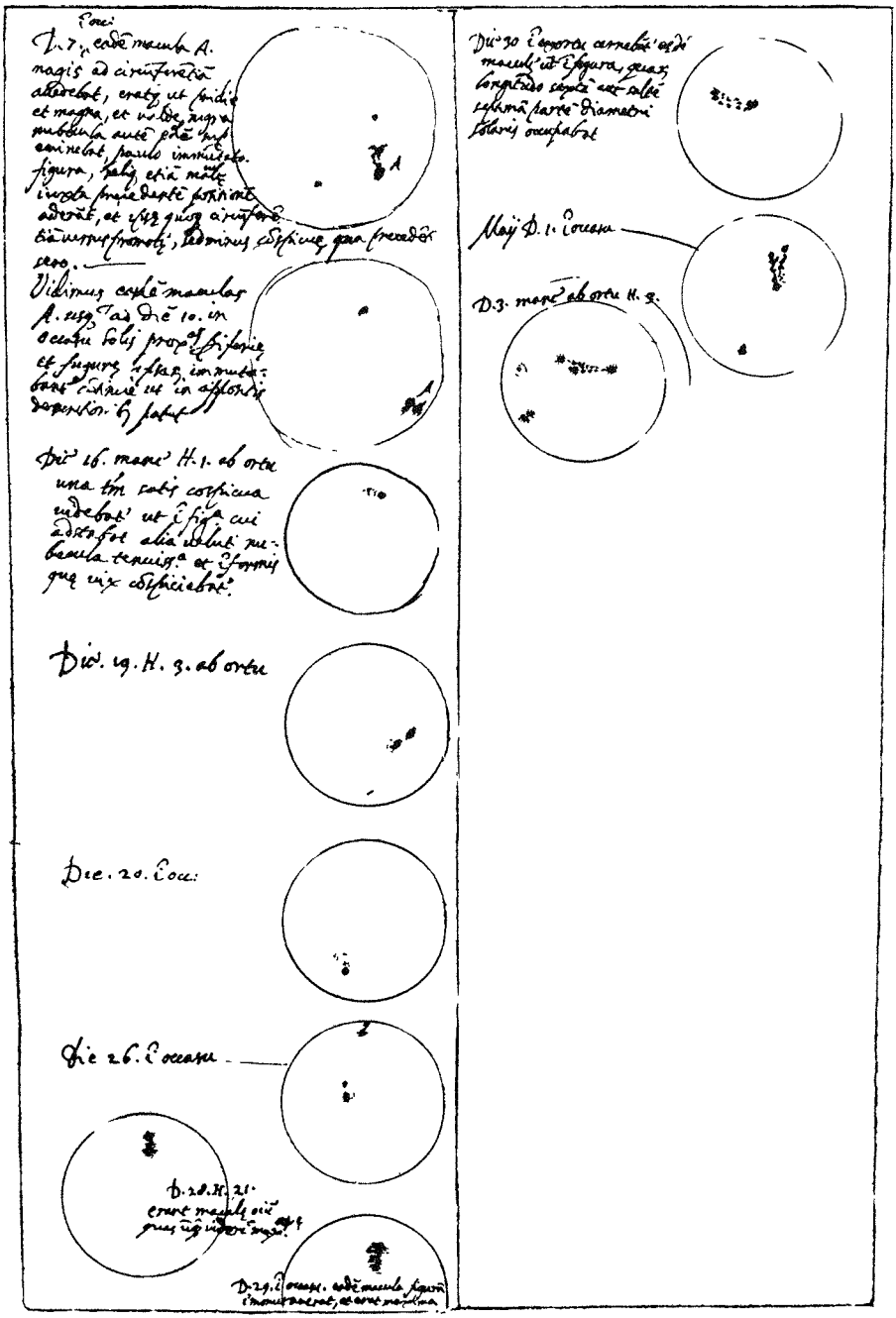
Contribution to Atomic Science

Galileo's concern with the nature of matter furthered the revival of atomism during the scientific revolution. He returned to the principle expressed by Democritus: The world is composed of atoms and a void.

He suggested that atoms have differences in number, weight, shape, and velocity, and these differences cause our senses to perceive different substances by taste, smell, sound, or touch.



Galileo's drawings of the satellites of Jupiter, 1610.



Galileo's drawings of sunspots.

PIERRE GASSENDI

A French philosopher and priest, Pierre Gassendi (ga-sawn-dee) was born in Champtercier, Provence, January 22, 1592, and died in Paris, October 24, 1655.

Biographical Details

Born of poor parents in southern France, Gassendi showed remarkable mental powers at an early age. He was sent to college at Digne and at the age of 16 was invited to lecture at the college.

After he earned his doctor of theology degree, he joined a holy order and taught philosophy and theology. Later he traveled to Belgium and Holland and then settled in Paris to teach and write.

He increasingly moved away from Aristotelian philosophy toward a more scientific view of the world. He was an admirer of Epicurus and Copernicus and wrote biographies of both men.

Scientific Achievements

Although primarily a philosopher and writer, Gassendi was also a mathematician and astronomer. He was the first to observe the transit of Mercury in 1631, confirming the convictions of Johann Kepler, the German astronomer.*

From Epicurus he learned the notion of the atomic nature of matter, and he enlarged on this thesis, thus helping to bridge a gap of 19 centuries in atomism.

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*Kepler calculated the times when Venus and Mercury would cross (or transit) the face of the sun. These crossings had never before been observed. Kepler died in 1630.

Contribution to Atomic Science

Gassendi's chief contribution lay in his influence. He strongly advocated experimentation in science. His views affected those of the famous chemist, Robert Boyle.

As a priest, he was able to avoid the connection between atomism and atheism that the Greeks had made, and this helped stimulate further study of atomic theory.

RENE DESCARTES

Sometimes called the father of modern philosophy, René Descartes (day-cart) was born at La Haye, near Tours, France, on March 31, 1596, and died in Stockholm, Sweden, on February 11, 1650.

Biographical Details

Descartes suffered from poor health for most of his life. As a young man, he had a chronic cough and was allowed to stay in bed as much as he wished. Throughout his career he did much of his work in bed.

A brilliant student, he pursued an erratic course as a young man, going first to Paris and then to Holland, where he joined the army. For 5 years he served in various army posts in Holland, Germany, and Hungary. Then he retired, using his inheritance to travel widely throughout Europe.

He ultimately settled in Holland where he lived his most productive years as a private scholar and philosopher. In the last year of his life he went to Sweden to become the royal philosopher to Queen Christina.

Scientific Achievements

In addition to his philosophy, Descartes made important contributions to mathematics, physics, optics, physiology, and psychology.

His philosophy began by his doubt of everything. But the fact that he could doubt implied the existence of someone who was doubting. He came to this conclusion: "I think, therefore I am."

In mathematics his most important achievement was his combination of algebra

and geometry into analytical geometry, a new branch of mathematics. This paved the way for the development of calculus by Isaac Newton.

In physics, Descartes accepted the notion of atoms as developed by Gassendi. He was a mechanist about the physical world, but he also held that a God existed apart from the physical world, and that this God had created the mechanistic world. Thus, Descartes believed that there were two worlds, a material world of atoms, and a spiritual world of nonatoms.

Contribution to Atomic Science

Descartes was the first modern philosopher to formulate complete dualism, that is, to make a sharp distinction between soul and body, mind and matter.

Thus Descartes made a further effort to reconcile an atomic theory of matter with a spiritual culture. But his real contributions came in his work in mathematics, which opened doors for future atomic scientists and physicists.

ROBERT BOYLE

Robert Boyle, sometimes called the father of modern chemistry, was born at Lismore Castle, Munster, Ireland, on January 25, 1627, and died in London, December 30, 1691.

Biographical Details

Boyle was the fourteenth child of the great Earl of Cork. A prodigy, he learned to speak Latin and French before he was 8, when he was sent to Eton. At 11 he traveled abroad with a French tutor, and he was in Italy studying the works of Galileo at age 14 when Galileo died.

When he returned to England, he decided to devote his life to scientific study and research. He took up residence in Oxford and later in London where he helped to found the Royal Society of London, the first great scientific organization.

He was a devout Christian and left his inheritance to provide lectures for the promotion of the Christian faith.

Scientific Achievements

One of Boyle's first discoveries, called Boyle's Law, states that the volume of gas varies inversely with its pressure.

He discovered the role of air in the propagation of sound, the expansive force of freezing water, and he did extensive experimentation on refractive powers, crystals, electricity, color, hydrostatics, and specific gravities.

Most important, perhaps, he gave chemical evidence that was later useful in developing atomic theories. As a chemist, he developed a technique for breaking down a substance into its most elemental parts. He called this chemical analysis.

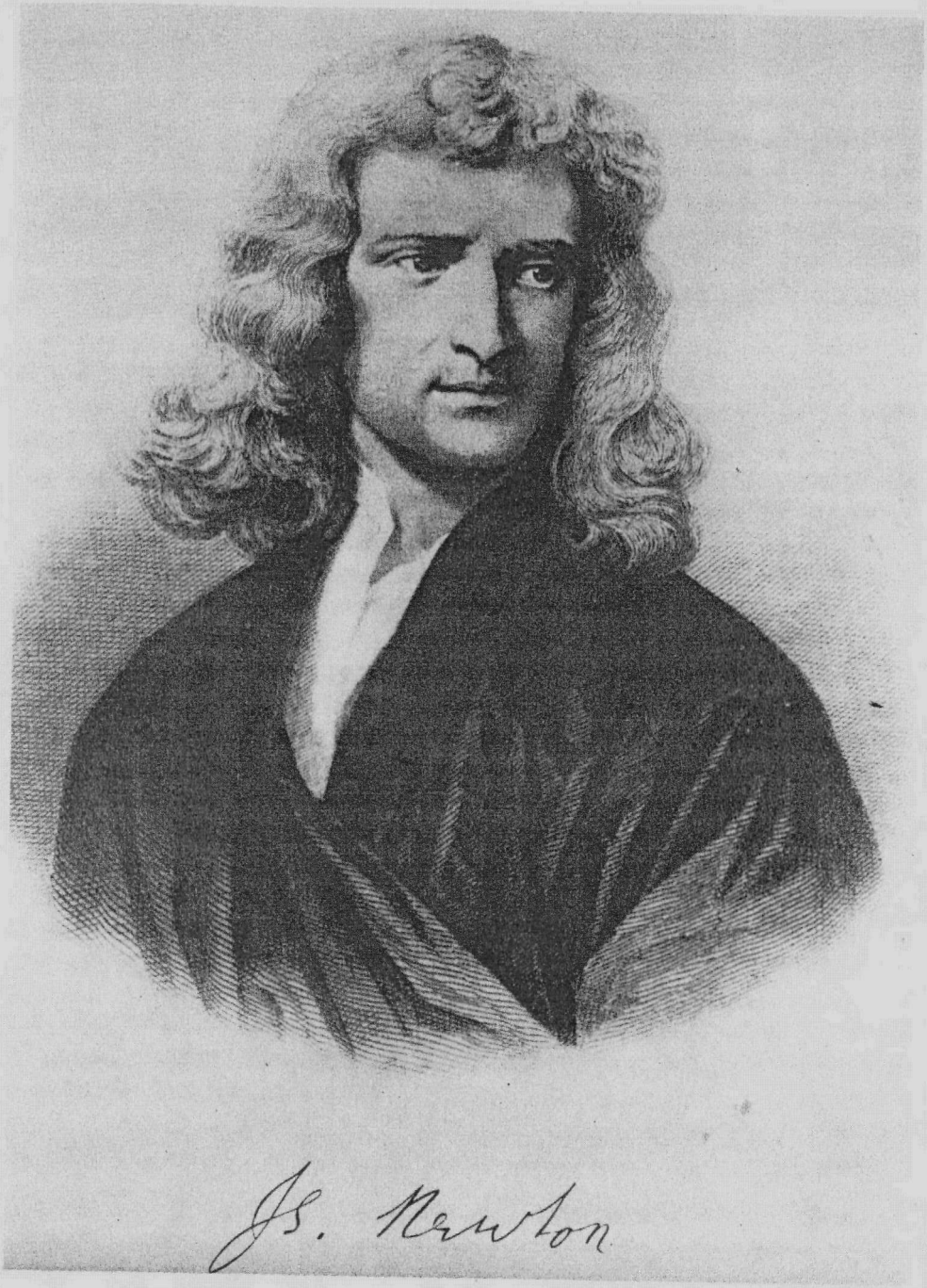
He threw out the old Aristotelian idea that the basic elements were fire, air, water, and earth, and even the later notion that all matter was salt, sulfur, and mercury.

Instead, he said that an element was a material that could be identified by scientific experiment and could not be broken down into still simpler substances.

Contribution to Atomic Science

Boyle's greatest contribution to atomic science was his denial of the Aristotelian notion of four elements, and his definition of an element, which is still usable today.

His work in chemistry had wide influence on later atomic scientists, particularly on Antoine Lavoisier.


Js. Newton

ISAAC NEWTON

Father of modern physics and one of the greatest scientists in all history, Isaac Newton was born in Woolsthorpe, Lincolnshire, England, on Christmas Day 1642 and died in London on March 20, 1727.

Biographical Details

Newton's father, a small landowner, died before Isaac's birth. The son had to help his mother on the farm, but he was also able to attend grammar school.

He was not a distinguished student at first, but at the age of 19 he entered Trinity College, Cambridge. By the time he was 27, he knew more about mathematics than his teacher who resigned to become a churchman. Newton filled the vacancy and became a professor of mathematics.

Newton did most of his creative thinking during his twenties and early thirties. But it wasn't until 1687 that he published his *Principia Mathematica,* which is generally considered the greatest scientific work ever written. His second important work, *Opticks,* was published in 1704.

Newton was knighted and elected to Parliament. He served as President of the Royal Society that Boyle had founded, and was Master of the Mint for England. When he died, he was buried with state honors in Westminster Abbey. He was probably the most celebrated scientist of all time.

Scientific Achievements

Newton's supreme scientific work was his system of universal gravitation. He went back

to his farm in 1665 to avoid the plague,* and during this time he worked out the law of gravity and its consequences for the solar system. He later remarked to a friend that he got the idea while watching an apple fall from a tree in his orchard.

Every particle of matter in the universe, he wrote, attracts every other particle with a force varying in inverse proportion to the square of the distance between them and directly proportional to the product of their masses.

Newton also formulated important laws of motion, including the laws of inertia and the famous law which states that for every action there is an equal and opposite reaction. This is the law on which modern rocket thrust is based.

Newton also developed infinitesimal calculus, which has become an essential mathematical instrument for computation in engineering and higher branches of mechanics.

Finally, among many other achievements, he made much progress in optics, especially in spectrum analysis. He was able to break up light into a spectrum of rainbow colors. This helped to suggest the later discovery that the color differences in a light spectrum were the result of differences in atomic structure.

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*A disease, sometimes called the Black Death, which caused about 75 million deaths in Europe and Asia in the 14th century. It reoccurred occasionally in the following centuries, and it was common for people to leave cities in the hope that they would run less risk of contracting the illness away from population centers.

Contribution to Atomic Science

Newton's contributions to mathematics and his statement of laws of motion enabled later scientists to calculate the movements and form the laws of the internal universe of the atom.

BENJAMIN FRANKLIN

Benjamin Franklin, America's first great scientist, was born in Boston, Massachusetts, on January 17, 1706, and died in Philadelphia, Pennsylvania, on April 17, 1790.

Biographical Details

Franklin was the fifteenth child in a family of seventeen. Before he was a teenager he was working in his older brother's print shop. When his brother was sent to jail for printing an editorial against the governor, young Franklin became writer, editor, and printer of the newspaper.

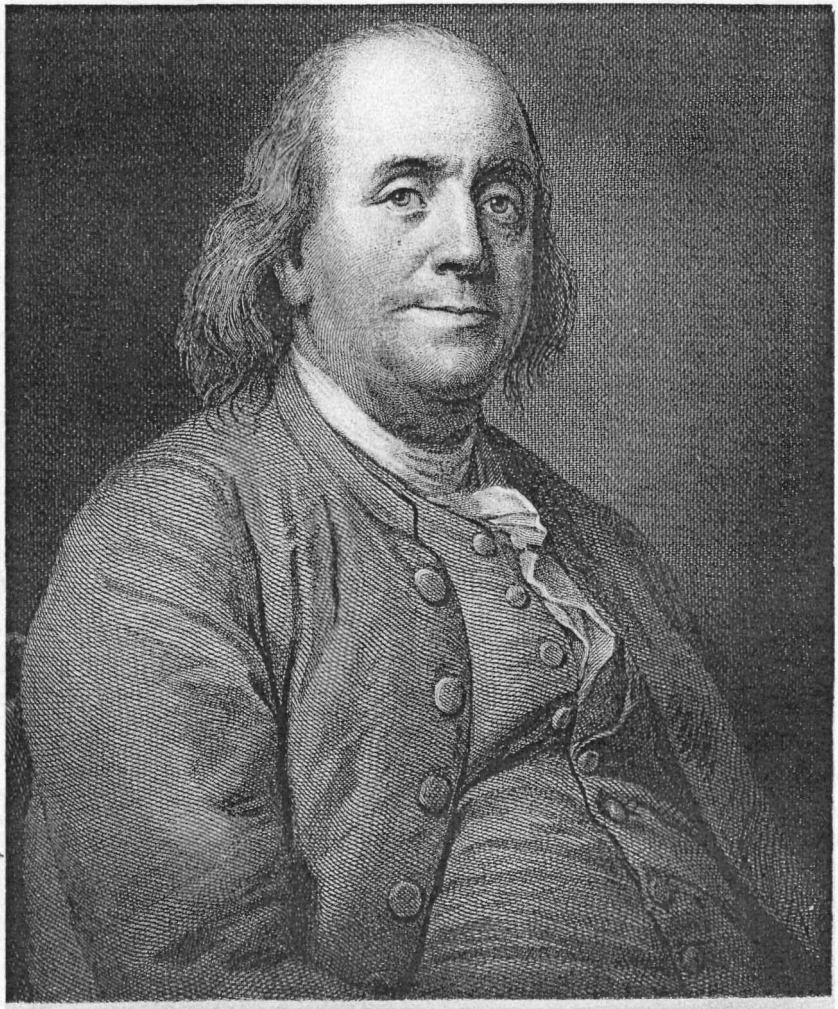
Later he traveled to Philadelphia and set up his own printing press. Soon he owned a number of print shops, and before he was 40 he was a wealthy man. He decided to devote himself to one of his hobbies, science, and to public service.

He became one of America's great statesmen—signer of the Declaration of Independence, member of the Constitutional Convention, and Ambassador to France.

His inventive mind not only contributed to science but also to public welfare. He founded hospitals, libraries, street lighting, a postal system, and the American Philosophical Society, modeled after the Royal Society of London of which he himself was the first American member.

Scientific Achievements

Franklin was more inventor than scientist, and he invented such things as an improved stove and bifocal eye glasses. He also contributed to meteorology, the science of weather.



BENJAMIN FRANKLIN.

Engraved by H. B. Hall from the original picture in Crayon, painted from life by J. S. Duplessis in 1783, and now (1868) in the possession of John Bigelow Esq.

His greatest contributions were in the field of electricity. In his famous experiment with a kite in a storm, he showed that lightning was electricity.

Franklin reasoned that electricity was a subtle fluid that could exist either in excess quantities or deficient quantities. An object with an excess of electricity would attract an object with a deficiency. He called these two forms positive electricity and negative electricity.

Contribution to Atomic Science

Franklin correctly defined the positive and negative force of electricity.

A century and a half after Franklin's work, atomic scientists showed that electricity was associated with subatomic particles when Ernest Rutherford stated that the atom contains a very tiny positively charged nucleus at its center, while very light negatively charged electrons make up the outer regions.

ANTOINE LAVOISIER

Antoine Laurent Lavoisier (la-vwah-see-yay) was born in Paris on August 26, 1743, and died there on May 8, 1794. He, like Robert Boyle, is often called the father of modern chemistry.

Biographical Details

Lavoisier was the son of a wealthy lawyer and received an excellent education. His father wanted him to study law but Lavoisier became interested in astronomy, and then geology, and finally settled on chemistry as his lifework.

By the age of 21 he had already done important chemical research. Like Franklin, he was also interested in public service, and he joined various citizens' commissions. On one of these projects he worked to provide a method of lighting towns.

At 23 he was elected to the French Academy of Sciences. He became involved with the French system of tax collecting, however, and when the French revolution came, he was arrested.

When he claimed he was a scientist, not a tax collector, he was told, "The Republic has no need of scientists." His head was cut off in a guillotine.

Scientific Achievements

Lavoisier fully destroyed the idea that fire was an element; this idea had persisted from early Greek times. He proved that combustion and respiration were forms of oxidation. He provided the names for oxygen and hydrogen, and he showed that diamonds were a form of carbon.

Portraits de M^r & M^me Lavoisier

D'après le tableau de David

He had been influenced by the work of Boyle, but two of Lavoisier's books clearly enabled him to share the "father of chemistry" title with Boyle. His work, *Methods of Chemical Nomenclature*, established a system for naming chemicals that is still used. His *Elementary Treatise on Chemistry* was the first great synthesis of chemical principles. It contained a remarkably accurate list of all the elements then known.

Lavoisier's greatest achievement was his statement of the law of conservation of mass: A given amount of matter, whether in the solid, liquid, or gaseous state, has a total mass, as measured by a weight that remains the same.

Contribution to Atomic Science

Lavoisier's total contribution to atomic science is enormous, but it was perhaps this last achievement, the law of conservation of mass, that had the greatest implication for future atomic work.

Lavoisier thus established that there was no ethereal, other worldly, or nonmaterial substance into which matter passed when it was heated, burned, or otherwise changed in form. The world of matter was the real and only world and did not change in basic atomic nature or weight when it changed in chemical combination.

Lavoisier and his wife. Engraving made from a painting by Jacques Louis David.

CLAUDE LOUIS BERTHOLLET

Claude Louis Berthollet (bur-toe-lay), French chemist, was born in Talloires, Haute-Savoie, France, on December 9, 1748, and died in Arcueil, a Paris suburb, on November 6, 1822.

Biographical Details

Berthollet was educated as a physician at the University of Turin. He studied chemistry under Lavoisier, however, and turned his attention to that science.

He was elected to the French Academy of Science in 1781. When the revolution came, he avoided the fate of his teacher, Lavoisier, and escaped with his life.

When Napoleon came to power, he made Berthollet a senator and a count. And when the Bourbons returned to authority, they made him a peer.

Scientific Achievements

Berthollet joined with Lavoisier in establishing a new chemical nomenclature. He did research on various elements and chemicals, including chlorine and ammonia.

His greatest achievement was his theory that the rates of reaction were proportional to the concentration of acids.

Contribution to Atomic Science

Berthollet's theories were ignored at first, but they became important with the rise of physical chemistry in the late 19th century, which preceded the work of the great atomic chemists.

JOSEPH LOUIS PROUST

Joseph Louis Proust (proost), a French chemist, was born in Angers, France, on September 26, 1754, and died there on July 5, 1826.

Biographical Details

Proust was the son of a druggist and grew up in an atmosphere of chemistry. As a young man he moved to Paris and set himself up in business as a druggist–chemist.

One of his early enthusiasms was the new sport of ballooning, and he was one of the first to go up in a balloon in 1784.

He traveled to Spain shortly before the outbreak of the French revolution and thus avoided the fate that befell his older colleague, Lavoisier. He spent two decades in Madrid before political trouble caused the ruin of his laboratory; he then retired to France.

Scientific Achievements

Proust made several important chemical investigations into the nature of various substances, especially sugar.

One significant element of his work was his success in proving Berthollet wrong on several important analyses of compounds.

Most important, however, his careful chemical analysis showed that all compounds contained elements in certain definite proportions, which Berthollet had denied. This law of definite proportions is sometimes called Proust's law.

Contribution to Atomic Science

Proust's law of definite proportions helped persuade John Dalton that elements must occur in the form of atoms, and this paved the way for Dalton's theories of atomism.

WILLIAM HYDE WOLLASTON

William Hyde Wollaston (wool'us-tun), English chemist and physicist, was born in East Dereham, Norfolk, England, on August 6, 1766, and died in London, December 22, 1828.

Biographical Details

Wollaston was the second of fifteen children born to an English clergyman. He studied medicine at Cambridge University, and after receiving his medical degree in 1793, he was a practicing physician for 7 years.

He then retired to devote himself to research. He had already made a reputation for himself as a scientist. He was only 27 when elected to the Royal Society, and in 1806 he was elected its Secretary.

His experiments with platinum production enabled him to earn a small fortune and made him financially independent. He kept his process a secret and arranged for the publication of his methods only after his death.

Scientific Achievements

Wollaston made contributions to several fields of science. He invented a goniometer to measure the angles of crystal faces, which greatly advanced mineralogical research.

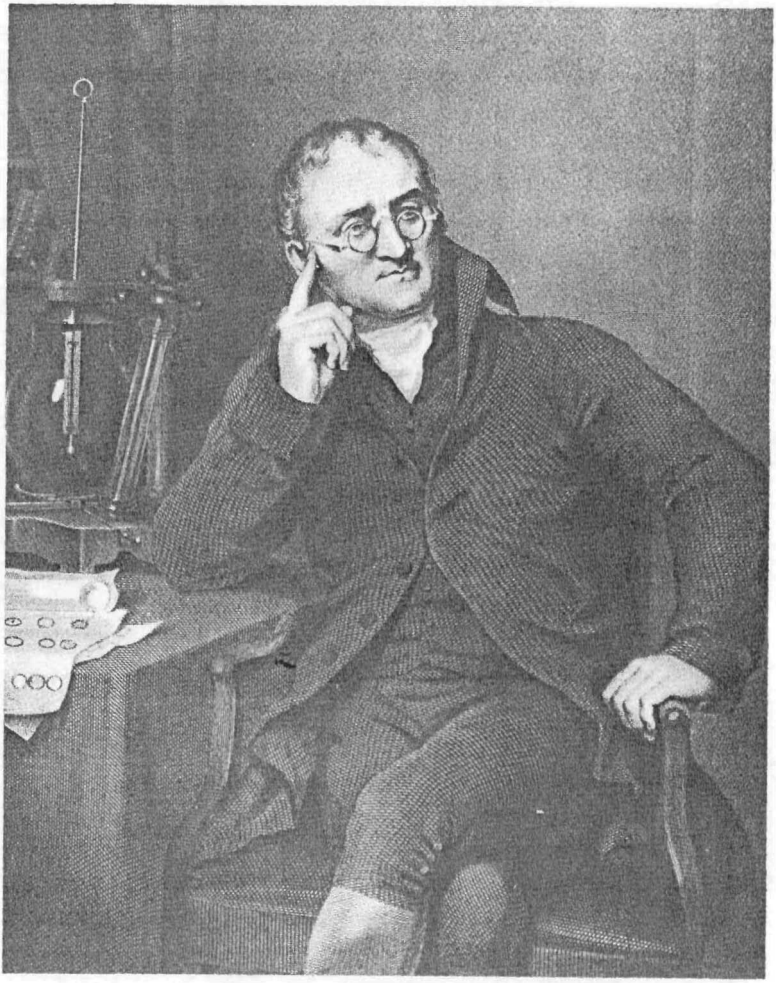
He worked in the fields of electricity and optics, continuing the work of such men as Franklin and Newton. In optics, he was the first man to demonstrate ultraviolet light in the spectrum.

Most important for the field of atomic science, Wollaston isolated and named two

elements, rhodium, element number 45, and palladium, element number 46.

Contribution to Atomic Science

Wollaston was among the first of a long line of chemists and physicists who for 150 years would help isolate and name the elements in the Periodic Table of Elements until more than 100 elements were discovered.



JOHN DALTON

John Dalton, an English chemist, was born in Eaglesfield, Cumberland, England, on September 6, 1766, and died in Manchester on July 27, 1844. He is the father of modern atomic theory.

Biographical Details

Dalton was the son of a poor weaver. His parents were Quakers and he was a devout member of that faith.

He received his early education from his father and at a Quaker school in his hometown. When his teacher retired, Dalton replaced him. He was then 12 years old.

He remained a teacher for most of his life. When he was 27 he moved to Manchester and taught college there until the college was moved. He then became a public and private teacher of mathematics and chemistry, and worked in his laboratory when he wasn't teaching.

Scientific Achievements

Dalton's first scientific work was in meteorology; he made weather records every day for 46 years and wrote a book about weather when he was 27. He also made the first study of color-blindness, a subject of personal interest since he himself was color-blind.

But his important work was in the field of atomic chemistry. He studied Newton and Boyle, and experimented with gases and Proust's law of definite proportions. He formulated his own law of multiple proportions in 1803, based on his observation that the same elements combined in different proportions to produce different substances.

In his work, Dalton deduced that gases were composed of particles of matter, just as he thought solids were. This led him to the conviction that all matter was made of particles called atoms.

He proposed his atomic theory in 1803 and published his ideas in a book, *New System of Chemical Philosophy*, in 1808. He maintained that atoms were alike in everything except their mass (or weight) In chemical reactions atoms preserve their identity and are not destroyed.

He tried to work out the relative weights of atoms, but his calculations were wrong although the principle was correct He was, however, the first to establish a table of atomic weights.

Contribution to Atomic Science

Dalton occupies an important place in the history of atomic hypotheses, from Democritus and Newton to his own day, primarily because he based his theory on scientific observation rather than philosophical speculation.

After Dalton's work was published, there was serious opposition to atomism. It was not until the beginning of the 19th century that it gradually became accepted and atomic theory became the basis of all chemistry.

AMEDEO AVOGADRO

The Count of Quaregna, Amedeo Avogadro (ah-vo-gah'dro), an Italian physicist, was born in Turin, Italy, on June 9, 1776, and died in that same city on July 9, 1856.

Biographical Details

Avogadro was a petty Italian aristocrat, born just a few days before the American colonies declared their independence from Great Britain.

He lived his entire life in the city of Turin. He was educated at the University of Turin and later served there as a professor.

At the age of 35, in 1811, he published his most important work, which contained two hypotheses about the nature of atoms in gases.

Scientific Achievements

Avogadro's paper suggested that all gases, under the same conditions of temperature and pressure, contain the same number of molecules. He also suggested that a molecule may contain more than one atom.

He thus made a distinction between the chemical atom, the smallest part of matter that can enter into combination, and the physical molecule, the smallest particle that can exist in a free state. This theory helped to explain some errors in calculation that Dalton had made.

Avogadro suggested that if water was composed of two atoms of hydrogen and one atom of oxygen, and if the oxygen in a molecule of water weighed eight times as much as the hydrogen in the molecule, then the individual atom of oxygen must be

sixteen times as heavy as the hydrogen atom, not eight times as Dalton had insisted.

Contribution to Atomic Science

Avogadro's idea ultimatelv helped scientists establish the correct relative weights of the atoms in the elements, and also their valences (or the wav in which the elements combine with each other). Unfortunately, it was not until 2 years after his death in 1856 that a fellow countryman, Stanislao Cannizzaro (kahn-nee-zah-row), proved experimentally the correctness of Avogadro's thesis.

Today we use Avogadro's name when we speak of the number of atoms or molecules present in an amount of substance that has a mass respectively equal to its atomic or molecular weight in grams. This is called "Avogadro's Number".

HUMPHRY DAVY

A founder of physical chemistry, Humphry Davy was born in Penzance, Cornwall, England, on December 17, 1778, and died in Geneva, Switzerland, May 29, 1829.

Biographical Details

Davy was the eldest son of a woodcarver who died when Davy was 16 years old. Although he was more interested in poetry, he had to take a job as a druggist's apprentice, and this led him to science.

He read Lavoisier's textbook and decided to pursue chemistry as his career. At the age of 23 he became a lecturer at the newly founded Royal Institution in London. His

lectures, based on his work in chemistry, became widely popular and 11 years later, at 34, he was knighted.

He became president of the Royal Society in 1820, but failing health, probably caused by close contact with poisonous chemicals, prevented him from serving for very long. He spent his last years traveling in Europe seeking better health.

Scientific Achievements

Davy's early work with nitrous oxide enabled him to be the first to find an anesthetic. He also did work on heat and maintained that it was a form of motion; this was a more accurate thesis than Lavoisier's.

Most important was his work with electricity. He made use of what we now call electrolysis to aid in the analysis of chemical compounds. Among his discoveries using this method were the isolation of element 19, which he named potassium, and element 17, which he named chlorine.

He also isolated for the first time such elements as barium, strontium, calcium, magnesium, and sodium. He proved that potash and soda, commonly thought of as elements, were really compounds.

He invented the Davy lamp for miners, which let them work safely even in the presence of explosive gases. He tried to use electricity for illumination, but he could not perfect the process.

His safety lamp burns oil. Inside the lamp a wire gauze cylinder of mesh forms a cage around the flame. If firedamp, the deadly gas in mines that causes explosions, is present, a pale blue flame appears around the central flame when the wick on the lamp is lowered.

This warns a miner to leave the spot immediately

Contribution to Atomic Science

Although he did not fully accept Dalton's atomic theory, Sir Humphry Davy nevertheless made many important advances in the isolation of elements

JOSEPH LOUIS GAY-LUSSAC

French chemist and physicist, Joseph Louis Gay-Lussac (gay-loo-sack) was born in St. Leonard in central France, on December 6, 1778, and died in Paris on May 9, 1850.

Biographical Details

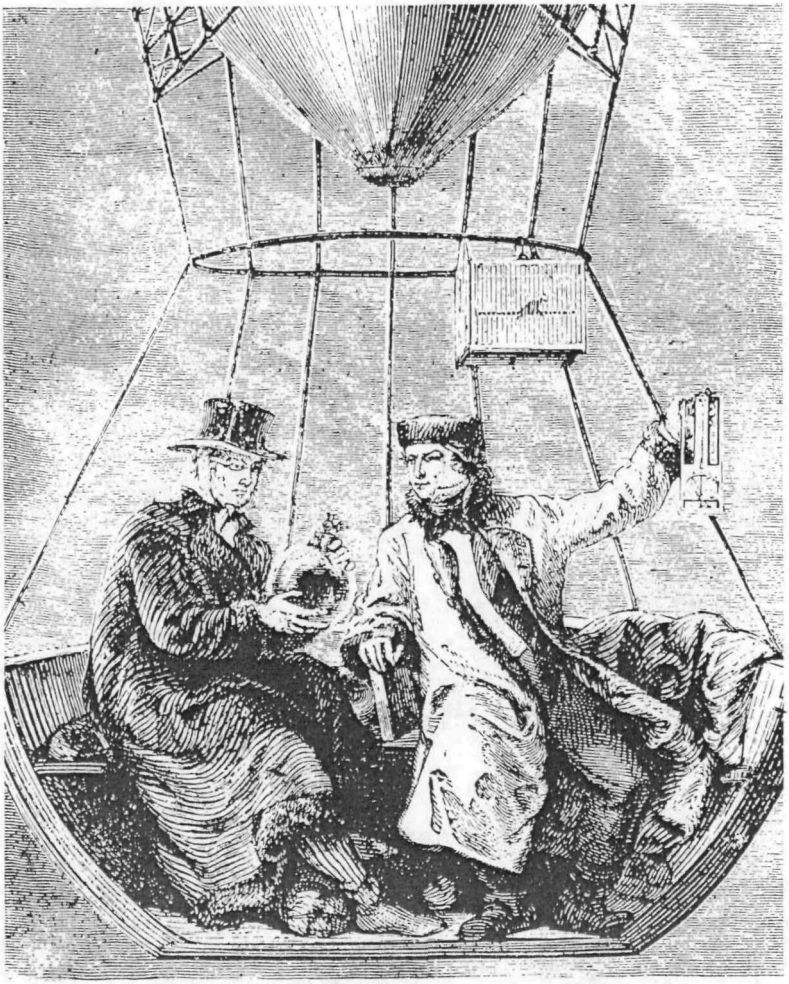
Son of a French provincial judge, Gay-Lussac received his early education at home. When he was 16 he was sent to Paris to complete his studies.

He became one of Berthollet's laboratory assistants, and at the age of 30 was a professor of chemistry and physics at the Sorbonne, a university in Paris. He was an early balloon enthusiast and ascended to 23,000 feet in a hot-air balloon to make experiments on the composition of the atmosphere.

He was elected to the French Academy of Sciences while still a young man, but he spent the last part of his life in public service rather than science. In 1831, at 53, he was elected to the French Chamber of Deputies and 8 years later to the Chamber of Peers.

Scientific Achievements

Like Dalton and Avogadro, Gay-Lussac studied the nature of gases and their molecular and atomic structure. He worked out the law of combining volumes, which states that gases form compounds with each other in simple, definite proportions. These proportions could now be expressed in formulas. For example, water was composed of two parts hydrogen and one part oxygen, and hydrogen chloride was made of one part hydrogen and one part chlorine.



Gay-Lussac and J. B. Biot making a balloon ascension to study the behavior of a magnetic needle and the chemical composition of the atmosphere at high altitudes. Gay-Lussac was then 25 years old.

He was interested in discovering new elements, and he isolated boron 9 days before Davy completed the same experiment. He also proved that iodine was a separate element, not a compound.

Contribution to Atomic Science

Gay-Lussac's work proved that Dalton's idea of combining gases by weight alone was insufficient, since his method of calculating atomic weights was wrong. Gay-Lussac's law of combining volumes would be most useful to Berzelius in helping to determine a table of atomic weights.

JÖNS JAKOB BERZELIUS

A Swedish chemist, Jöns Jakob Berzelius (bur-zel-e-us) was born in Väversunda, Sorgard, Sweden, on August 20, 1779, and died in Stockholm on August 7, 1848.

Biographical Details

An orphan at an early age, Berzelius obtained a fine education through the generosity of his stepfather. After attending a local school, he went to Uppsala University, where he studied chemistry and medicine and received his M.D. degree in 1802.

He then became an assistant professor of botany and pharmacy in Stockholm and in 1807 was made a full professor of chemistry. By 1830 he was considered the great chemical authority of the world, and his textbook on chemistry was printed in five editions.

While still a young man, at 29, he was elected to the Stockholm Academy of Sciences. In 1818 the king of Sweden, Charles XIV, made him a noble, and in 1835 he became a baron on his wedding day at the age of 56.

Berzelius' wife, Betty.

Scientific Achievements

Berzelius was one of the first followers of Dalton's atomic theory. He set out to determine a list of atomic weights for all elements then known. It proved to be a remarkably accurate list, although Berzelius did not yet perceive the importance of Avogadro's distinction between atoms and molecules.

Berzelius also suggested a system for designating elements and compounds by using the first letter of the Latin name. Oxygen was O for example, and hydrogen was H. Using

numbers to determine the proportion of elements in compounds, this system could provide a simple means for expressing the formula for all substances. Water, for instance, which was composed of one part oxygen and two parts hydrogen, could be expressed as H_2O.

Berzelius, with Davy, established the fundamental laws of electrochemistry, and he used this science to discover new elements such as selenium, silicon, and thorium. He was also one of the first to discover the rare element cerium, but a German scientist, Martin Klaproth, won the honor of being first by a few days.

Contribution to Atomic Science

Berzelius' table of atomic weights helped to establish Dalton's atomic theory firmly. It has been greatly improved upon but it is the basis for our Periodic Table of the Elements.

Berzelius' system of chemical notation and formula was widely used and has become the international language of chemistry.

Thus, after more than 2000 years of theorizing and experimenting with the nature of matter, the atomic theory was established on a sound footing by Berzelius and this would enable the next 150 years of atomic science to produce astounding achievements.

READING LIST

More information on the men in this booklet can be found in encyclopedias, in individual biographies listed in *Books in Print*, which you can use in most school and public libraries, and in the following books.

Elementary Books

Discovery of the Elements (sixth edition), Mary E. Weeks, Chemical Education Publishing Company, Easton, Pennsylvania, 1956, 910 pp., $10.00. Grades 9-12.

The Discovery of the Elements, Willy Ley, The Delacorte Press, New York, 1968, 256 pp., $4.95. Grades 7-9.

Elements of the Universe, Glenn T. Seaborg and Evans G. Valens, E. P. Dutton and Company, Inc., New York, 1958, 253 pp., $4.95 (hardback), $2.15 (paperback). Grades 6-9.

Men Who Mastered the Atom, Robert Silverberg, G. P. Putnam's Sons, New York, 1965, 193 pp., $3.30. Grades 7-9.

The Restless Atom, Alfred Romer, Doubleday and Company, Inc., New York, 1960, 198 pp., $1.25. Grades 9-12.

Advanced Books

Asimov's Biographical Encyclopedia of Science and Technology The Living Stories of More than 1000 Great Scientists from the Age of Greece to the Space Age, Isaac Asimov, Doubleday and Company, Inc., New York, 1964, 662 pp., $8.95.

The Autobiography of Science (revised edition), Forest Ray Moulton and Justus J. Schifferes (Eds.), Doubleday and Company, Inc., New York, 1960, 748 pp., $6.95.

The Flash of Genius, Alfred B. Garrett, Van Nostrand Reinhold Company, New York, 1963, 249 pp., $6.50.

A History of Science (fourth edition), Sir William Cecil Dampier, Cambridge University Press, New York, 1949, 527 pp., $7.50 (hardback); $3.45 (paperback).

A History of Science Ancient Science Through the Golden Age of Greece, George Sarton, Harvard University Press, Cambridge, Massachusetts, 1952, 646 pp., $12.00 (hardback), $2.65 (paperback) from John Wiley and Sons, Inc., New York.

A History of Science Hellenistic Science and Culture in the Last Three Centuries B. C., George Sarton, Harvard University Press, Cambridge, Massachusetts, 1959, 554 pp., $12.00 (hardback), $2.65 (paperback) from John Wiley and Sons, Inc., New York.

The World of the Atom, 2 volumes, Henry A. Boorse and Lloyd Matz (Eds.), Basic Books, Inc., Publishers, New York, 1966, 1873 pp., $35.00.

Alphabetical List of Names

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57	Library of Congress.
58, 60, & 61	*Discovery of the Elements*, Mary E. Weeks, Chemical Education Publishing Company, 1956.

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